Claims

1. A system for acquiring seismic data, comprising:
one or more sensor modules adapted to sense seismic data; and
one or more seismic recorders adapted to record seismic data and coupled to the sensor module;
wherein the sensor module comprises one or more accelerometers, and
wherein the accelerometers have one or more axes of sensitivity.

2. An apparatus for sensing seismic energy, comprising:
a sensor adapted to sense seismic energy;
wherein the sensor comprises one or more accelerometers, and
wherein the accelerometers include one or more axes of sensitivity.

3. An apparatus for sensing seismic energy, comprising;
a sensor adapted to sense seismic energy;
wherein the sensor comprises one or more micro-machined sensor elements.

4. An apparatus for synchronizing the operation of a sensor to a common time base, comprising:
a sensor module adapted to sense seismic energy;
wherein the sensor module comprises one or more sensors, and
wherein the sensor module further comprises a global positioning system receiver adapted to synchronize the operation of the sensors.

5. An apparatus for synchronizing the operation of a sensor to a common time base, comprising:
one or more accelerometers adapted to sense seismic energy; and
a seismic recorder coupled to the accelerometers;
wherein the seismic recorder comprises a global positioning system receiver adapted to synchronize the sensor.

6. An apparatus for determining the position of a sensor, comprising:
a sensor module adapted to sense seismic energy;
wherein the sensor module comprises a global positioning system receiver adapted to determine the location of the sensor module.

7. An apparatus with insensitivity to tilt for sensing seismic energy, comprising:
a sensor adapted to sense seismic energy;
a feedback control circuit adapted to provide force balanced feedback coupled to the sensor; and
a controller adapted to monitor the operation of the apparatus coupled to the sensor.

8. An apparatus for determining the orientation of a sensor, comprising:
a sensor module adapted to sense seismic energy; and
a controller adapted to control the operation of the apparatus coupled to the sensor module;
wherein the sensor module comprises a 3-axis magnetometer adapted to determine the orientation of the sensor module.

9. An apparatus for determining the coupling between a sensor and the ground, comprising:
a sensor adapted to sense seismic energy;
a crystal assembly adapted to provide a force in order to measure the ground coupling of the sensor coupled to the sensor; and
a controller adapted to control the operation of the apparatus coupled to the sensor.

10. An apparatus for measuring the vector fidelity of a sensor, comprising:
a sensor adapted to sense seismic energy;
a crystal assembly adapted to provide a force in order to measure the vector fidelity of the sensor coupled to the sensor; and
a controller adapted to control the operation of the apparatus coupled to the sensor.

11. A method of seismic sensing, comprising;
monitoring acceleration in a plurality of directions.

12. A method of seismic sensing, comprising;
monitoring acceleration in a plurality of directions; and
monitoring pressure variations.

13. A method of operating a sensor adapted to sense seismic energy with insensitivity to tilt, comprising:

providing a forced feedback compensation to the sensor.

14. A method of determining the tilt angle of a sensor module adapted to sense seismic energy, comprising:

providing a forced feedback compensation to the sensor; and

measuring the steady-state gravity field over a predetermined time period.

15. A method of determining the tilt angle of a sensor module, comprising:

calibrating the sensor module to determine tilt information;

storing the tilt information within the sensor module; and

measuring an effect of gravity on the sensor module.

16. A method of manufacturing a sensor assembly having a plurality of axes of sensitivity, comprising:

minimizing cross-axis sensitivity;

minimizing the tolerance of the sensitivity; and

providing axes of sensitivity that are approximately orthogonal;

wherein the sensor assembly operates with a vector fidelity uncertainty less than about 1%.

17. A method for acquiring seismic data, comprising:

coupling a seismic recorder to a sensor module including a plurality of accelerometers.

18. A method of determining the orientation of a 3-axis sensor, comprising;

performing a 3-dimensional measurement of a gravity field;

determining a gravity vector;

performing a 3-dimensional measurement of a magnetic field;

determining a magnetic vector; and

determining the direction of magnetic north and gravity down.

19. A method of sensing seismic energy, comprising:

synchronizing the operation of a seismic sensor module;

wherein synchronizing the operation of a seismic sensor module

comprises using a global positioning system signal from a global positioning system receiver within the sensor module.

20. A method of sensing seismic energy, comprising:
determining the position of the seismic sensor;
wherein determining the position of the seismic sensor comprises using a global positioning system signal from a global positioning system receiver within the sensor module.

21. A method of synchronizing the acquisition of seismic data, comprising:
receiving a signal containing time information; and
controlling the operation of one or more accelerometers adapted to sense seismic energy and one or more seismic recorders using the signal.

22. A method of determining the location of the acquisition of seismic data, comprising:
receiving a signal containing position information; and
determining the position of one or more seismic sensors using the signal.

23. A method of determining the degree of coupling between a sensor assembly and the ground, comprising:
generating a force;
recording a response of the sensor assembly to the force; and
analyzing the response.

24. A method of determining the vector fidelity of a sensor assembly, comprising:
generating a force;
recording a response of the sensor assembly to the force; and
analyzing the response.

25. A method of determining the orientation of a sensor module, including one or more accelerometers, without direct measurement, comprising:
generating a force at a plurality of source points;
recording a response of the sensor module to the force; and
analyzing the response.

26. A method of determining the state-of-health for a sensor module, including a plurality of accelerometers and a seismic recorder, comprising:
sending a bitstream to the sensor module;
decoding, capturing, and looping-back the bitstream to the seismic recorder; and
capturing and analyzing the bitstream by the seismic recorder,
wherein analyzing the bitstream comprises determining a malfunction of the sensor module.

27. A method of determining the state-of-health for a sensor assembly, including an ASIC coupled to a seismic recorder, comprising:
sending a bitstream to the ASIC;
decoding, capturing, and looping-back the bitstream to the seismic recorder; and
capturing and analyzing the bitstream by the seismic recorder;
wherein analyzing the bitstream comprises determining a malfunction of the sensor assembly.

28. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an ASIC, comprising:
reading contents of the ASIC; and
validating the contents of the ASIC.

29. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising:
operating the accelerometer; and
monitoring the operation of the accelerometer;
wherein monitoring the operation of the accelerometer comprises monitoring the accelerometer for instability to indicate a malfunction of the accelerometer or an excessive external acceleration.

30. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising:
exciting the accelerometer with a bitstream; and
acquiring, analyzing and judging an output signal generated by the

accelerometer;

wherein judging an output signal comprises judging a magnitude of the output signal to indicate a malfunction of the accelerometer.

31. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising:

exciting the accelerometer with a bitstream; and

acquiring, analyzing and judging an output signal generated by the accelerometer;

wherein judging an output signal comprises judging a phase response of the output signal to indicate a malfunction of the accelerometer.

32. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising;

exciting the accelerometer with a bitstream; and

acquiring, analyzing and judging an output signal generated by the accelerometer;

wherein judging an output signal comprises judging a total harmonic distortion of the output signal to indicate a malfunction of the accelerometer.

33. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising:

operating the accelerometer for a period of time; and

analyzing an output signal generated by the accelerometer;

wherein analyzing an output signal comprises detecting an excessive root-mean-square amplitude response of the output signal to indicate a malfunction of the accelerometer or a noisy environment.

34. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including an accelerometer, comprising:

operating the accelerometer; and

analyzing an output signal generated by the accelerometer;

wherein analyzing an output signal comprises analyzing an offset and a gravity cancellation magnitude of the output signal to detect a change in the inclination of the accelerometer.

35. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy including three accelerometers, comprising:
operating the accelerometers; and
monitoring one or more output signals generated by the accelerometers;
wherein monitoring one or more output signals generated by the accelerometers comprises monitoring a vector sum of the self-measured coefficients of gravity of the output signals to detect a malfunction of the sensor assembly.

36. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including three accelerometers, comprising:
operating the accelerometers;
driving two of the accelerometers at a reference frequency;
monitoring an output signal generated by the undriven accelerometer; and
rotating through all the accelerometers;
wherein monitoring an output signal comprises monitoring the magnitude of the reference frequency in the output signal of the undriven accelerometer to detect a malfunction of the sensor assembly.

37. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy, including one or more accelerometers, comprising:
operating the accelerometers for a period of time;
removing DC offset from one or more output signals generated by the accelerometer to produce one or more resulting signals;
transforming the resulting signals from the accelerometers from Cartesian coordinates into polar coordinates; and
analyzing the polar coordinates;
wherein analyzing the polar coordinates comprises analyzing one or more peak and root-mean-square amplitude results to indicate a malfunction of the sensor assembly or a noisy acquisition environment.

38. A method of determining the state-of-health for a sensor assembly adapted to sense seismic energy including one or more accelerometers, comprising:

(a) operating the accelerometers;

(b) monitoring one or more output signals generated by the accelerometers;

(c) analyzing the output signals;

(d) changing the orientation of the sensor assembly; and

(e) repeating steps (b), (c) and (d) for a plurality of orientations;

wherein analyzing the output signals comprise calculating the sensor's angles with respect to gravity from a vector sum of the self-measured coefficients of gravity in any orientation; and

wherein analyzing the output signals further comprises analyzing sensor's angles with respect to gravity to indicate a malfunction of the sensor assembly.